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THE BEAN LADYBIRD.

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With a report on "The Bean Ladybird in Colorado, in 1919."

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INTRODUCTION.

In the semiarid region of the Southwest, where an immense acreage of beans is grown annually, a destructive insect known as the bean ladybird, bean beetle, "bean bug," and spotted bean beetle[1] does great injury. Indeed, it is to the bean crop what the Colorado potato beetle is to the potato, a pest of the highest importance in the region which it inhabits.

The beetle devours all parts of the bean plant—leaves, flowers, and growing pods. Its main food supply, however, is the leaves, through which it cuts irregular holes (Pl. I; III; IV, fig. 1). Its injuries,

[1] *Epilachna corrupta* Muls.; order Coleoptera, family Coccinellidae.

NOTE.—This insect was under the observation of the junior author (who died September 10, 1918), from 1914 to 1917. The life-history investigations were conducted in an open-air insectary at Rocky Ford, Colo.; and some field operations were conducted also at Pueblo, Fort Collins, and Colorado Springs, Colo., and at Maxwell and French, N. Mex.

so far as is known, are practically confined to beans, and no variety seems to be exempt from injurious attack. This insect has been observed feeding on various forms of the kidney bean (*Phaseolus vulgaris* et al.), including string, pole, navy, and tepary or Mexican, and on the lima bean (*Ph. lunatus*). Of these string beans are favorites. On one occasion the soy bean (*Soja hispida*) was attacked. The beetles, unlike those of the bean leaf-beetle (*Cerotoma trifurcata* Forst.), show no tendency to injure very young plants and the larvæ work on the lower surface of the leaves, skeletonizing large, irregular areas without cutting the epidermis or upper skin. (Pl. II, III.)

It is fortunate that its field of operations is limited, both as regards the crop plants affected and the territory over which it ranges. It has been estimated that it does an annual damage in New Mexico varying from 5 to 100 per cent of the crop, the average loss being conservatively placed at 10 per cent.

This species is remarkable in that it is one of two species of ladybirds occurring in the United States[1] which feed exclusively on vegetation, the other forms of the ladybird family being predacious and subsisting largely on plant-lice, or aphids, and the eggs of insects.

SYNONYMY.

The bean ladybird was described by Mulsant in 1850 (1, p. 815)[2] under the name by which it is known in economic literature, *Epilachna corrupta*. In the original description in which this name appears, printed under No. 90, *E. varivestis* is also described as No. 91, yet Crotch (3, p. 62), followed by Gorham (8, p. 242), recognized the latter as the proper name for the species, and relegated *corrupta* to synonymy, in which case the strict law of priority has not been followed. This species has evidently been described under at least a half dozen names, but as there is no means of deciding positively the exact term to apply to the species under consideration, *Epilachna corrupta* is here used to avoid further confusion, although *E. varipes* Muls. was described first and is acknowledged by Crotch and Gorham to be the same species. The name used by Bland (2), *E. maculiventris*, described in 1864 from the Rocky Mountain region of Colorado, undoubtedly applies to this species and naturally falls into synonymy.

DESCRIPTION.

THE ADULT.

The adult (fig. 1, *b*) is a robust beetle, oval in outline, and about one-fourth of an inch in length by about one-fifth of an inch in

[1] The other is known as the squash ladybird (*Epilachna borealis* Fab.).

[2] Reference is made by figures in parentheses to "Literature cited," p. 20.

width. The color of the newly developed adult is yellow, gradually darkening with age to a grayish brown. Each elytron or wing-cover is marked with eight small black spots of variable size.

Technical descriptions of the genus and species follow:

GENUS EPILACHNA.

Large, pubescent species related to Chilocorus. Sides of prothorax only slightly curved and broadly explanate; those of elytra rather strongly reflexed; epipleuræ horizontal, broadly concave, not distinctly extended to sutural apex. Metasternal and ventral lines well-defined, legs moderately retractile; femora not deeply sulcate beneath, tibiæ with an acute external edge, and shallow groove for reception of tarsi; claws cleft, with lower cusp nearly as long as upper.

EPILACHNA CORRUPTA MULS.

Form oblong, more narrowly oval than *borealis* and distinctly smaller, dull in luster, densely pubescent, and very closely, unequally punctate; color grayish brown; head and pronotum without spots. Each elytron ornamented with

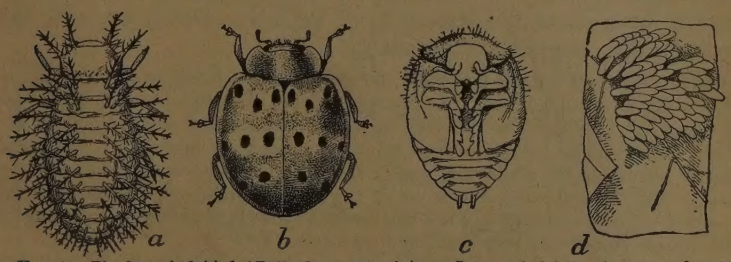


FIG. 1.—The bean ladybird (*Epilachna corrupta*): *a*, Larva; *b*, beetle; *c*, pupa; *d*, egg mass. About three times natural size.

eight spots or dots of varying size in three rows; three small sub-basal spots in a broken row, median less basal; three in a transverse subparallel row just before the middle, usually larger than sub-basal, median usually a little larger, and two near apical fourth, placed near inner fourth and outer third. Lower surface darker or concolorous with legs, which are pale throughout.

Length 6.5–7.8 mm.; width 4.8–5.4 mm.

The so-considered Mexican variety, *E. varipes* Muls., differs mainly from the species under discussion as it occurs north of Mexico in having the two subapical spots united or coalescing, forming an arcuate fascia. All spots are also larger and surrounded by a lighter aureole. The typical *varivestis*, as figured by Gorham, shows these aureoles, but they are less pronounced in many specimens from the United States.

Specimens occasionally occur of a more or less pronounced buff color, but these usually are not fully colored, being more or less immature when killed for mounting.

THE EGG.

The egg is dull pale yellow, elliptical in outline, approximately twice as long as wide, a little larger at the base or attached end than

at the apex. The surface is strongly sculptured. The length of the egg is 1.25 mm.; the width 0.6 mm.

The eggs are deposited on end on the lower surface of the bean leaves (Pl. IV, fig. 1) in irregular masses, varying from half a dozen to about 75, with an average of between 40 and 50. (See fig. 1, *d*.)

THE LARVA.

The larva is yellow and the body is armed with long, formidable, strongly branched spines, darker at the tips. When full grown these spines, although somewhat irregular, are arranged in rows both longitudinally and transversely, as shown in the accompanying illustration (fig. 1, *a*). The head is moderately prominent, as are the mandibles and other mouth-parts, which with the eyes are darker than the other parts. The legs are rather long and stout and the anal segment is obtusely and roundedly produced. The newly hatched larva measures about one-sixteenth of an inch in length and the full-grown larva about five-sixteenths of an inch. Descriptions of the larval stages, as given by Merrill (21), follow:

First Stage. When the yellowish larva first frees itself from the egg the spines are closely appressed. As the chitin dries, the spines become erect and are seen to be branched at and near the tip. Later the tips of the branches become darker. The larva is about 1.3 mm. long by .6 mm. wide. The body tapers sharply in the abdominal region and is recurved downward. There is a row of four spines across the front of the rather pronounced pro-thorax. On the rest of the body there are six longitudinal dorso-lateral rows, the spines of the outside rows being very small and very few. * * *

Second Stage. After the first moult the larva is 2 mm. long and the tip of the abdomen is slightly more curved than in the first stage. The spines are longer and more branched. The dark tips are not so pronounced. The rows of spines are the same in number but more distinct. * * *

Third Stage. After the second moult the larva is 4 mm. long. The spines are longer, more branched from the sides, and dark tipped. The rows are now easily seen. In this stage the larva seems to be rather humpbacked, the highest and widest portion of the body being about the middle portion. The abdomen tapers sharply, the anterior end slightly, only. * * *

Fourth Stage. At the beginning of the fourth stage the larva is 5.4 mm. long and it increases to nearly 1 cm. in length before the fourth moult. The chief difference between the larva in this stage and in the last is in the size.

THE PUPA.

The pupa (fig. 1, *c;* Pl. V) is ovate in outline, and approximately the size of the adult. It is yellow with brown markings. Anteriorly it is roundedly subtruncate and posteriorly tapers strongly toward the apex. The surface is sparsely beset with bristle-like setæ and long hairs. The head is folded down in front over the thorax and the posterior legs reach below the wing-sheaths. The apex terminates in two elongated processes, conical at the base and black at the extreme tips. The larval exuviæ are pushed down and form a protection for the last abdominal third of the body. (Pl. VI.) Length 7–7.5 mm.; width 4–4.5 mm.

DISTRIBUTION.

The bean ladybird occurs in the States of New Mexico, Arizona, Colorado, and Texas. In the last mentioned State it is restricted to localities in the western part. It is also said to occur in Kansas and Arkansas but not as a pest. There is a single record of a beetle, presumably a "chance find," having been taken at Ogden, Utah, but it is not positively known that the species breeds in that State.

The bean ladybird, as has been stated, is to the bean industry in the West what the Colorado potato beetle is to the potato crop in the East, and its origin is obviously the same—Mexico, where it is widely distributed. It is also found throughout Central America. It has been observed at elevations of from 3,000 to 7,000 feet above sea level in New Mexico, and of about 4,000 to approximately 5,000 feet in Colorado.

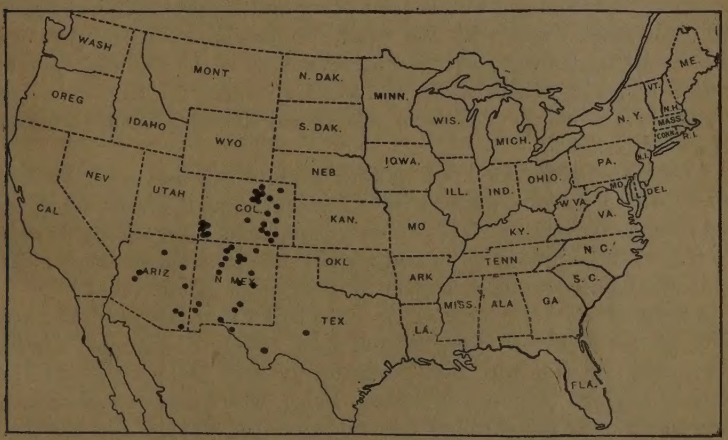


FIG. 2.—Map showing known distribution of the bean ladybird in the United States, June 1, 1919.

According to the observations of Dr. C. P. Gillette, State entomologist of Colorado, the species inhabits the foothills of the Rocky Mountains, seldom straying far out on the plains, with the exception of down the Arkansas Valley in Colorado. Further details in regard to its distribution in that State are furnished on page 13.

The known distribution of the bean ladybird in the United States is indicated in figure 2.

DANGER OF FUTURE SPREAD.

In regard to the future distribution of this pest it must again be compared with the Colorado potato beetle, first because of its obviously similar origin. It may have been introduced at an even earlier date than the latter, since the cliff dwellers in the region which the beetle inhabits in the United States included tepary beans

in their dietary. From an economic standpoint it is a potential pest of the type of the Colorado potato beetle and the boll weevil and it is singular that it has never migrated to any noticeable extent as have those pests, since it is probably capable of extended flights. One reason that may be assigned for this is its practical limitation to a single food plant, while the potato-feeding insect infests virtually all of the Solanaceae, including the weeds, and is capable of breeding continuously on all species of Solanum and probably on other genera. There is no reason to suppose that this insect may not by flight increase its present range materially some time, although not necessarily in the near future. Its further dissemination, however, would doubtless be slow and never as rapid as in the case of the comparatively fleet-winged and more adaptable Colorado potato beetle. The reasons, then, for its failure to have become more widely distributed are: Its limitation to a single food plant and its probable incapacity for protracted flight with the wind. Moreover, it is probably not capable of inhabiting such varied climates as is the Colorado potato beetle, a species which seems to have no respect for life zones but which thrives equally well from subtropical southern Texas to boreal Manitoba.

In the case of the Colorado potato beetle it can not as yet be definitely stated, as some authors have assumed, that it breeds wherever potatoes are grown, but it is perfectly capable of doing so, and it may be that in the course of time, many years undoubtedly, the bean ladybird will be distributed wherever its food plant is cultivated.[1]

Another factor which strengthens the belief that the bean ladybird will, in the course of time, become more widely disseminated is its very close relationship, both structurally and biologically, to the squash ladybird (*Epilachna borealis* Fab.), which ranges from South America northward through Central America, Mexico, and the Antilles, along the Mexican and Atlantic seaboard States to Maine and Canada. Obviously the squash-feeding species has a similar tropical origin, beginning farther southward and extending much farther northward. Instead of progressing straight northward it has followed more nearly the coastal lines and has a totally different distribution in the United States, being somewhat restricted to the East[2] just as the bean ladybird is restricted to the Middle West.

The present distribution of this species as outlined in the map would indicate that we may expect its establishment some time in the future in near-by counties in the States of Utah, Wyoming, Ne-

[1] The predacious ladybird *Hippodamia convergens* Guér. is capable of accommodating itself to practically all climes and countries, with the exception of areas where the temperature is so high or so low that few forms of plant and insect life are able to survive.

[2] It occurs, though not as a pest, in certain other regions remote from the region specified, e. g., in Kansas and Arkansas.

braska, and Oklahoma, and later in southern California. There may even exist a wider distribution than is now known in Texas, since the localities inserted on the map plainly show such a possibility.

LIFE HISTORY AND HABITS.

SEASONAL HISTORY.

In the Arkansas Valley of Colorado, and in regions having a similar climate, two generations or "broods" of the bean ladybird develop annually.

The winter is passed in the adult stage, the beetles hibernating under tufts of grass, weeds, old vines, rubbish, and similar material, in or about the fields and gardens in which they developed. The overwintered beetles emerge from their hibernating quarters about the middle of June and, after a brief interval of feeding, mate and begin to deposit eggs.

The first eggs hatch in about a week and the adults of the first generation develop shortly after the middle of July. After an interval of a week or ten days eggs are deposited by the first generation of beetles and from these the first adults of the second generation develop. This occurs during the latter part of August or early September. A portion of the adults of the first generation and all those of the second generation deposit no eggs until June of the following year. The beetles go into hibernation during the last days of September and the first of October and, as previously stated, remain dormant until about the middle of June of the succeeding year.

It is somewhat remarkable that the beetles remain in hibernation during the last days of May and the first half of June when high temperatures, from 90° to 95° F., often prevail.

The egg-laying period of the overwintered beetles, which includes individuals of both the first and second generations, extends from shortly after the middle of June until about the 1st of August, although occasionally some of these beetles live and deposit eggs throughout the summer. The egg-laying period of the beetles of the first generation which deposit eggs during the first season extends from soon after the middle of July until well into September. Reproduction, then, continues from about the middle of June until the beans are destroyed by killing frosts in late September or early October. The insects usually cause a maximum amount of damage during July and August. The larvæ, especially those more than half grown, are voracious feeders and, as a rule, cause vastly more injury than do the beetles.

REPRODUCTION AND DEVELOPMENT.

The life-history studies of the bean ladybird were conducted in Colorado in an open-air insectary at Rocky Ford. The insects were confined in cloth-covered battery jars and fed on the foliage of

string beans. A pair of beetles which developed in late August, 1914, mated August 29 and were isolated. These beetles commenced hibernation October 12, and on November 10 the rearing cage, containing earth and some dead bean leaves under which the beetles rested, was placed in the laboratory cellar. The cage remained in the laboratory cellar until May 20, 1915, when it was again placed in the open air. The beetles emerged from hibernation on June 15, and began feeding. The first eggs were deposited June 18, and from this stock the species was reared for two seasons (1915 and 1916) without a break. The record for 1915 is given in Table I and that for 1916 in Table II.

TABLE I.—*Generations of Epilachna corrupta in 1915.*

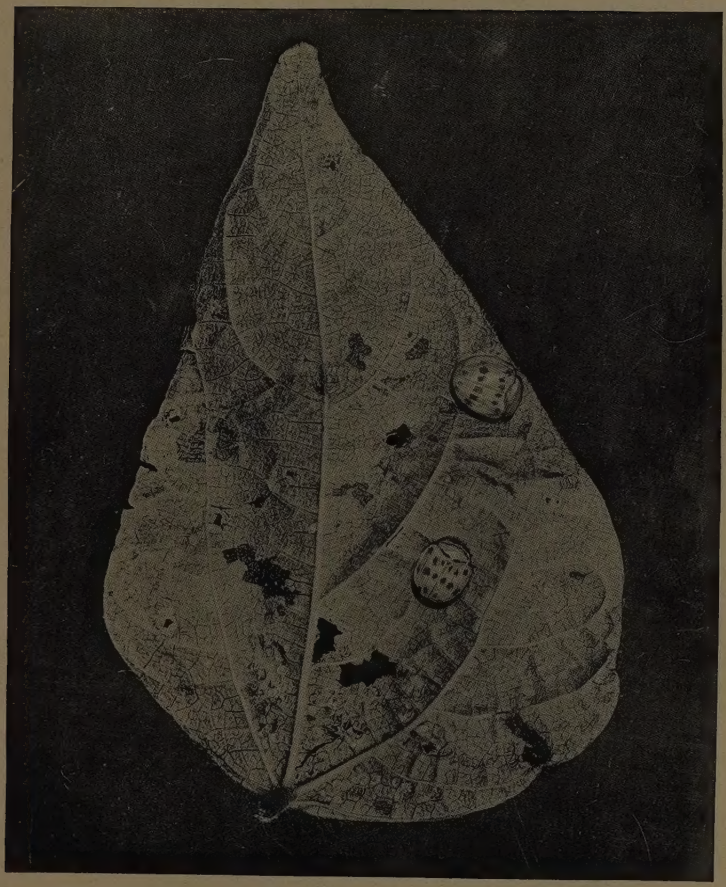
Life-history event.	First generation issued.	Second generation appeared.
Adults developed	Aug., 1914	July 19, 1915
First eggs deposited	June 18, 1915	July 30, 1915
First eggs hatched	June 25, 1915	Aug. 5, 1915
First larvæ matured	July 12, 1915	Aug. 23, 1915
First larvæ pupated	July 13, 1915	Aug. 24, 1915
First adults developed	July 19, 1915	Sept. 1, 1915
	Days.	*Days.*
Egg period	7	6
Larval period	18	19
Pupal period	6	8
Total duration	31	33

TABLE II.—*Record of the generations of Epilachna corrupta in 1916.*

Life-history event.	First generation issued.	Second generation appeared.
Adults developed	Sept. 1, 1915	July 17, 1916
First eggs deposited	June 18, 1916	July 30, 1916
First eggs hatched	June 25, 1916	Aug. 5, 1916
First larvæ matured	July 10, 1916	Aug. 21, 1916
First larvæ pupated	July 11, 1916	Aug. 23, 1916
First adults developed	July 17, 1916	Aug. 31, 1916
	Days.	*Days.*
Egg period	7	6
Larval period	16	18
Pupal period	6	8
Total duration	29	32

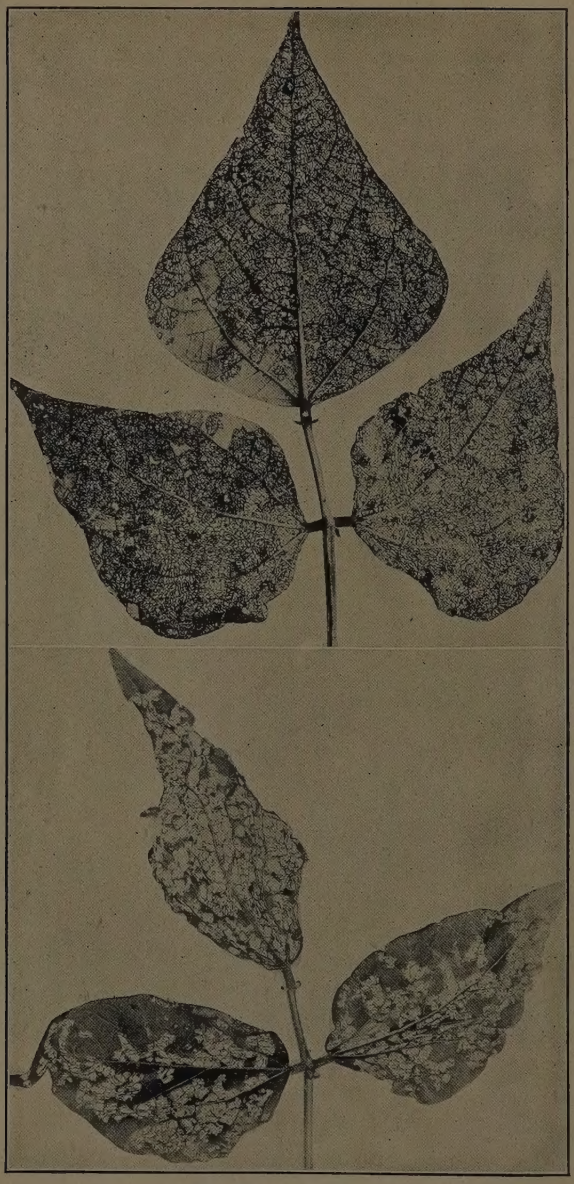
The 19 beetles which developed September 1 fed until September 23, when hibernation began. The cage was placed in the laboratory cellar November 10, 1915, and was removed to the open May 3, 1916. June 12, 16 beetles issued from hibernation, 3 having died during the winter, and began feeding. One pair mated June 13, and the record of the progeny is given in Table II.

The female died September 9. The male went into hibernation October 5, and was later destroyed. In this case the egg-laying



THE BEAN LADYBIRD.

Beetles beginning work on under surface of leaf.



THE BEAN LADYBIRD.

Bean leaves showing injury by beetle.

THE BEAN LADYBIRD.

Bean leaves skeletonized by the bean ladybird. Beetle above; pupæ in middle; larva at left near bottom. Somewhat enlarged.

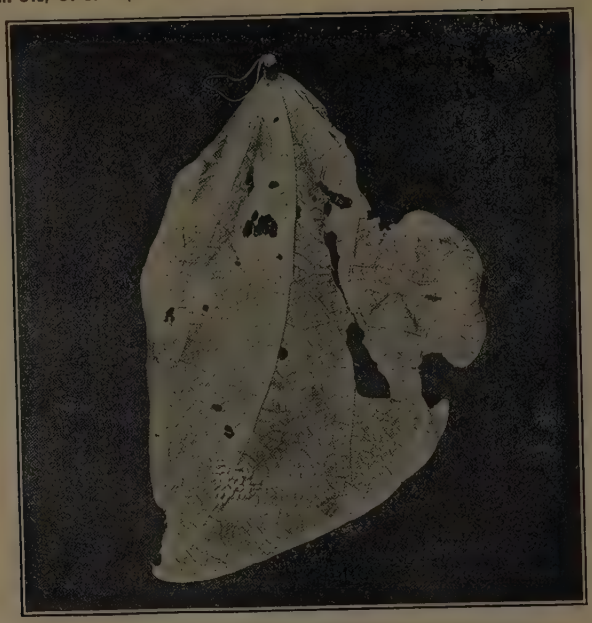


FIG. 1.—EGG MASS ON LOWER PORTION OF BEAN LEAF.

FIG. 2.—LARVÆ AT WORK ON UNDER SURFACE OF LEAF.

THE BEAN LADYBIRD.

THE BEAN LADYBIRD.

Pupæ formed on injured bean leaf.

THE BEAN LADYBIRD.

Cluster of bean leaves showing natural form of pupation on lower surface of leaf, and larva ready to transform on leaf at right.

period extended from July 25 until September 2, a total of 40 days. With other females this period covered from 35 to 70 days.

The life cycle from egg to adult and the periods of the stages by days are given in Tables III and IV respectively.

TABLE III.—*Life cycle of Epilachna corrupta.*

Event.	Date.	Event.	Date.
	1916.		1916.
Eggs deposited	Aug. 10	Larvæ molted	Aug. 30
Larvæ hatched	Aug. 18	Larvæ reached maturity	Sept. 3
Larvæ molted	Aug. 21	Larvæ pupated	Sept. 5
Larvæ molted	Aug. 25	Adults developed	Sept. 12

TABLE IV.—*Periods of stages of Epilachna corrupta.*

Instar.	Number of days.	Instar.	Number of days.
Egg period	8	Fourth larval stage period	6
First larval stage period	3	Pupal period	7
Second larval stage period	4		
Third larval stage period	5	Total	33

The beetles which developed August 31 fed, without mating or depositing eggs, until October 5, when they began hibernation. November 10, 1916, the cage was placed in the laboratory cellar and removed to the open April 17, 1917. The beetles issued from hibernation June 15, 1917, and were then killed, closing the record.

Records of egg-laying were obtained by confining single pairs of beetles, immediately after mating and before the first eggs were deposited, in small rearing jars. The beetles fed on bean leaves and the eggs were removed as deposited and counted. The number of eggs deposited by eight females of the first and second generations were: 504, 552, 616, 636, 850, 942, 1,147, and 1,516, respectively, or an average of 845 eggs to a single beetle.

A detailed record of the female of one of these pairs of beetles, which developed July 17, 1916, and mated July 22, is given in Table V.

TABLE V.—*Egg-laying record of a single female of Epilachna corrupta in 1916.*

Date.	Number of eggs deposited.	Date.	Number of eggs deposited.
1916.		1916.	
July 25	52	Aug. 15	56
July 28	50	Aug. 18	58
July 29	53	Aug. 21	55
Aug. 1	52	Aug. 23	52
Aug. 3	55	Aug. 26	52
Aug. 5	51	Aug. 28	54
Aug. 6	53	Sept. 2	51
Aug. 9	52		
Aug. 11	54	Total	850

In experiments conducted in New Mexico by Merrill (21) the period of incubation was between 4 and 9 days. The duration of the larval stage was between 15 and 21 days. The pupal period was between 3 and 5 days, and the total developmental period lasted between 22 and 28 days.

HISTORY AND LITERATURE.

The bean ladybird was described by Mulsant in 1850 (1) from Mexico as *Epilachna corrupta* and its injuries were observed in New Mexico at about the same period.

In 1883 Riley (4) published an editorial on this species with quotations from a letter from Prof. George H. Stone, which contains our first known account of the food and injurious habits of this insect. Attack by larvæ and adults was observed on leaves and pods of wax beans at Colorado Springs, Colo., August 26, 1882.

It was not until a lapse of six years that attention was called to further injury by this insect. At that time Judge J. F. Weilandy (5, 6) wrote, July 23, 1889, of injuries at Springer, N. Mex., stating that this "bean bug" committed great depredations in bean fields, often destroying them entirely. The Mexicans had found that late planting, about the middle of July, acted as a preventive of its ravages. In a letter dated July 30, in the same year, he directed attention to injury at Watrous, N. Mex., and stated that the pest had been known in that region for about 40 years. He also furnished specimens from which were recorded, editorially, the habits of two predacious ladybirds, which will be mentioned later under "Natural enemies," of feeding on the eggs of this species.

In 1892 Prof. C. P. Gillette (7) gave an account of this pest in Colorado, furnishing illustrations of the stages and manner of work.

In 1897 Rev. Henry S. Gorham (8) considered this species with the Coccinellidae of Central America, indicating the synonymy, and the distribution in Mexico, Guatemala, and Panama, with notes on variation and colored illustrations of the adult and of the larva. In this year also Mr. H. Griffin (9) reported injury at San Juan, N. Mex. Judge Weilandy furnished a list of the varieties of beans affected and reported on the effectiveness of Paris green which, although it killed the beetles, destroyed the plants as well.

In 1899 Col. Thos. L. Casey (11, p. 103) furnished a characterization of the beetle, comparing it with *E. borealis*. In 1900 Cockerell (13) stated that this species was the "bane of bean growers in New Mexico, from Chicorico Cañon * * * to the Mesilla valley." In 1902 A. N. Caudell (14) cited an instance of extreme injury to beans at Fort Collins, Colo., in 1901. The statement made by W. Knaus (15), in 1906, that this insect was damaging potato near Wootens, N. Mex., is, of course, incorrect. During 1907 Messrs.

Fall and Cockerell (16, p. 170) indicated by localities the distribution in New Mexico. In 1913 Dr. A. W. Morrill (19) published a note on the distribution of this species in Arizona. In 1915 E. O. Essig (20, p. 219) stated that this species was "said to be found in California," which is evidently incorrect as no definite locality is cited and the species is not known to breed in that State. During 1917 D. E. Merrill (21) published the first comprehensive account of this insect, with especial regard to its occurrence in New Mexico, furnishing details in regard to injuries, life economy, and distribution, and indicating methods of control. In most respects the results obtained in that State do not differ materially from those obtained in Colorado.

Popular accounts of the bean ladybird were published by Gillette (10) in 1898, Sanderson (18) in 1912, and by the writer in 1899 (12), 1907 (17, p. 109), 1917 (22, p. 28), and 1919 (23), as well as by others.

UNPUBLISHED RECORDS.

February 2, 1899, Mr. C. B. Metcalfe wrote of the bean ladybird and its injuries to the Mexican Bayo bean or frijole at San Angelo, Tom Green County, Tex. For many years prior to the date of writing growers had not succeeded in raising a crop of beans because of the ravages of this pest, which destroyed the plants by eating the leaves. Metcalfe described the larva as a humpbacked yellow insect about one-fourth inch long and of the color of sulphur, with a hairy-looking covering which changed afterward to the hard-backed grown "bug." He described the larva as destroying the green part of the leaves leaving only a thin tissue. During the same year Mr. James K. Metcalfe, Silver City, N. Mex., wrote that this species was quite injurious to beans in his vicinity, and furnished specimens in different stages. At this time, September 14, larvæ were quite scarce, most of those sent having transformed to pupæ.

August 8, 1904, Oscar Liffreing, Bernardo, N. Mex., sent specimens, mostly pupæ and newly developed beetles, with the report that they were devouring all of the early beans in that region. August 26 of the same year specimens were received from Mr. Liffreing, with report of injury to beans. July 26, 1905, Mrs. V. A. Armstrong reported injury to beans at Fort Collins, Colo., furnishing specimens of larvæ, and leaves and pods showing injury.

September 6, 1908, F. H. Headley reported injury at Fort Collins, stating that this insect was doing a great amount of damage to the bean crop in that section. July 15, 1909, B. F. Morris, Santa Cruz, N. Mex., wrote as follows: "I am sending some chinch bugs, the insect which is working destruction to the bean crop here, and is now depositing its eggs." During 1909 M. C. Stevenson, Espanola,

N. Mex., reported injury, July 24, to beans, furnishing samples of adults. August 11, M. A. Bishop reported injury at Tularosa, N. Mex. He wrote that for two years previously a small yellow bug covered with hairs had been eating the leaves of beans leaving nothing but a bare skeleton. Complaint was also made by Mrs. Katherine Courtney of injury to lima beans at Littleton, Colo.

May 28, 1910, Elias Clark, Alcalde, N. Mex., stated that this insect was very destructive to beans in that vicinity. January 11, 1909, John Block, Santa Cruz, N. Mex., described the larvæ, adults, and the work of this species on beans, requesting a remedy. July 6, 1915, Mrs. Ethel Mercer wrote from Denver, Colo., of little yellow larvæ which literally devoured the bean crop. They began on the leaves, and after these were gone they attacked the pods, as many as 15 being noted on a pod. Before the beans began to bloom the same insect ate the leaves "full of holes."

August 28, 1912, this species, according to Dr. A. W. Morrill, did considerable damage to beans at Prescott, Ariz. At that time it was abundant mostly in the pupal and adult forms. Between July and August of the following year, 1913, much damage was noted to pole beans at Cottonwood, Ariz. The insects practically ruined an entire field of about one-half acre. At that time full-grown larvæ and pupæ and a few egg batches and young larvæ were found. The hibernating adults had disappeared, only newly emerged, pale yellow adults being in evidence.

October 13, 1916, W. E. Marble wrote in regard to the growing of Mexican beans in the Arroyo Animas Valley of New Mexico, stating that the crop was greatly damaged by the larvæ of this ladybird which he described as of about the size of a navy bean, yellow in color, eating the leaves, and leaving only a network. This, he wrote, stops the growth of the plants and ultimately kills them. October 16, A. Warner, Sandy, Ariz., sent specimens, stating that the insect destroyed a crop in about 14 days, and that Paris green was ineffective.

Complaints were made during the year 1917 of injury at Wheatridge, Brewster, Colorado Springs, Rocky Ford, Pueblo, Denver, and Boulder, Colo.; Santa Fe and East Las Vegas, N. Mex.; Flagstaff, Ariz.; and Alpine, Tex. The last report was from T. F. Blaine, dated October 31, and was accompanied by specimens. D. E. Merrill also wrote of this species October 5, 1917, and of its occurrence in the vicinity of El Paso, Fabens, and Clint, in the El Paso Valley of Texas.

F. M. Wadley, scientific assistant, stated June 21, 1918, that the bean ladybird occurred at Wichita, Kans., but was more abundant in the western part of the State. August 6, Thomas H. Hudson complained of injury by this species to beans at Colorado Springs, Colo.

During January, 1919, A. E. Mallory, scientific assistant, wrote in regard to the occurrence of this species at Greeley, Colo., that he had observed the beetles feeding on the underside of the leaves of the mammoth soy bean (*Soja hispida*) in that vicinity. The previous December he found the beetles hibernating under a pile of bean vines. Until the receipt of this last record the species was believed to feed exclusively on table beans.

February 11, 1919, W. A. Williams, Venus, N. Mex., reported injuries by this species to pinto beans in that vicinity. Failure to obtain rain was ascribed as one of the causes of injury. Mr. Williams stated that "on beans these little 'bugs' eat the leaves full of holes and damage the crop considerably." During January and February a number of other complaints were made of injury by this species in New Mexico and Colorado. Other complaints of injury, unaccompanied by specimens, and requests for information in regard to methods of control have been received from other sources, notably Parsons, Kans., Jemez Springs and Nogal, N. Mex., Griffith, Colo., and Kirkland, Ariz.

April 3, 1919, the State entomologist, Dr. C. P. Gillette, collaborator, wrote in regard to the occurrence of this species in Colorado as follows:

> We have records of this species from the points which you mention and others near them, and also from Nucla, in the Paradox Valley, Montrose County; from Cortez, in Montezuma County; and from near Greeley, in Weld County. It seems likely that the infestations in the southwestern part of the State are from New Mexico. It has seemed very strange to me that this beetle keeps so close to the foothills, never going out far upon the plains, except down the Arkansas Valley. The beetle was abundant here when I first arrived at Fort Collins, 28 years ago, and it apparently has never occurred as far east as Greeley, about 24 miles from the foothills. I have found it to be a species about equally abundant every year, although there is some fluctuation in numbers. It was very bad last year in the northern section, from Pueblo to Fort Collins, along the eastern foothills, and extended a few miles into the plains.

Writing on this species September 2, 1919, Mr. Fabian Garcia, horticulturist, New Mexico Agricultural Experiment Station, State College, N. Mex., stated that this insect is a serious pest in New Mexico, particularly in the older bean-growing sections, and that it causes the bean growers there a lot of trouble and expense. He expressed the opinion that the losses could be materially reduced by properly spraying.

NATURAL CONTROL.

EFFECT OF CLIMATIC CONDITIONS.

Cold weather appears to be the most important natural check to the development of the bean ladybird in Colorado. This insect is a southern species which apparently has not become fully adapted to

northern climates. This is not a theory but is based on facts. It is indicated by the fact that many eggs, larvæ, and pupæ occur so late in the fall that they are killed by freezing. Many larvæ starve because the foliage of the bean plants on which they had been feeding was destroyed by early fall frosts. It is also not uncommon to find many dead adults in their hibernating quarters where they had been killed by winter temperatures.

FIG. 3.—The five-spotted ladybird (*Hippodamia 5-signata*), an enemy of the bean ladybird. Enlarged.

NATURAL ENEMIES.

The insect enemies of the bean ladybird are, as far as has been learned, not particularly effective in holding it in abeyance. The beetles are well protected by their firm elytra or wing covers and by a repellent yellow liquid which oozes from their knee joints in small drops when the insects are disturbed. This liquid possesses a disagreeable odor and doubtless a similar flavor, which, it is believed, may protect the beetles from the attacks of natural enemies.

June 27, 1916, two overwintered female beetles were collected at Rocky Ford, Colo., each with the egg of a tachinid fly attached to one of its elytra. One of these beetles died September 4, and the other September 9. Fertile eggs were deposited at frequent intervals from June 29 until September 5, and no parasites developed. This is the only evidence noted of insect parasites.

Morrill has reported an undetermined ant observed eating the eggs on one occasion.

FIG. 4.—Transverse-spotted ladybird (*Coccinella transversoguttata*): Adult beetle. Much enlarged.

The adults of three species of predacious ladybirds are known to be natural enemies of this insect. They are: The convergent ladybird (*Hippodamia convergens* De G.); the five-spotted ladybird (*Hippodamia 5-signata* Kby., fig. 3), and the transverse-spotted ladybird (*Coccinella transversoguttata* Fab., fig. 4).

These have been reported as destroying the eggs of the bean ladybird, and next to cold are the most effective known factors in its natural control in Colorado and neighboring States.

The first species occurs in abundance throughout the country and is our most useful ladybird, having been transported from one part of the country to another and to foreign countries. The other two are commonly found in the region inhabited by the bean ladybird, but more especially in the middle Northwest. Both species, however, extend their range to Washington and Oregon.

The larvæ are apparently well protected from insect enemies by the branched spines with which the body is armed. In one case, however, the larva of a lacewing fly (*Chrysopa* sp.) was observed sucking the juices from a partially grown Epilachna larva.

No insect enemies of the pupa and no fungous or other disease have been observed to affect the living insect in any stage.

PREVENTIVE MEASURES.

HAND PICKING AND BRUSHING.

The bean ladybird is difficult to control. In small gardens hand-picking the eggs, larvæ, and adults has given satisfactory results. The greatest measure of success has come from gathering and destroying the overwintered beetles soon after their emergence from hibernation and before they have had an opportunity to deposit eggs. The beetles, being sluggish like the Colorado potato beetle, are readily hand picked.

Another method which has afforded some degree of success consists in brushing the larvæ from the foliage to the earth between the rows. This can be accomplished by striking the plants with the bare hand, with a bunch of weeds, or with a paddle fashioned for the purpose from a shingle. If the brushing is done during dry hot weather very few, if any, of the larvæ are able to return to the plants.

CLEAN CULTURAL METHODS.

With the knowledge that the adults of the bean ladybird pass the winter under old vines, tufts of grass, weeds, and other useless material, the numbers of beetles may be materially reduced by burning in late fall or early spring all rubbish of this nature along ditches and fence corners and in similar locations. Everything possible should be done to destroy these winter quarters, as their destruction will afford a considerable measure of protection from injury, if done by a community year after year.

EARLY AND LATE PLANTING.

Proper attention to the time of planting will prevent considerable injury by this as well as many other species of insect pests.

By planting earlier than usual this can be accomplished, as well as by planting considerably later, or as late as a crop can be assured. Since the overwintered beetles do not begin to feed until very late, planting early will accomplish much, enabling the plants to make such good growth that insect damage coming late may be immaterial.

Late planting should be so timed that the plants will come up after the overwintered beetles have about ceased feeding and, at the same

time, early enough to secure a good crop before frost time. No definite time can be assigned for early or late planting for the entire range of this species; it is a matter for the growers themselves to determine. Community work should accomplish much along this line, in determining both the times for planting and the effect of this method.

It has been suggested that early planting be practiced in a community for a series of years and then late planting for a year or two succeeding this.

Whatever can be done toward lessening the number of insects in a community during a given year will have a correspondingly greater effect for the coming season.

DIRECT MEASURES OF CONTROL.

EXPERIMENTS WITH INSECTICIDES.

Numerous spraying experiments were made with arsenate of lead, Paris green, arsenite of zinc, and nicotine sulphate. The experiments were conducted on moderately infested plots of string beans. The spray was applied to both the upper and lower surfaces of the leaves with a portable compressed-air sprayer, fitted with an extension rod, elbow, and disk-type nozzle having a fine aperture.

ARSENATE OF LEAD.

Arsenate of lead was applied at the rate of 1½, 2, 2½, and 3 pounds in powdered form in 50 gallons of water. The spray adhered well and evenly to the foliage, but the effect was very uncertain on the bean foliage as was also the killing effect on the insects. The injury from burning varied greatly with the age and tenderness of the plants, the older, tougher foliage usually escaping appreciable injury, while on the younger, more tender plants the burning effect was serious, especially where the stronger doses were applied.

In summing up the experiments in spraying with powdered arsenate of lead the results were so uncertain that one is hardly justified in recommending this insecticide as a reliable agent for controlling the bean ladybird on string beans.

One experiment was made with arsenate of lead paste at the rate of 6 pounds to 50 gallons of water. This burned the beans so badly that they were almost completely destroyed. Most of the larvæ were killed, but the majority of the beetles escaped injury. This test indicates that paste arsenate of lead is even more injurious to bean foliage than the powdered form, and that the killing effect on the adults of the bean ladybird is equally uncertain.[1]

In experiments conducted by Merrill (21) in New Mexico powdered arsenate of lead was used at the rate of 2 and 2½ pounds to 50 gallons of water without damage to the plants. Most of the beetles

[1] The tests herein mentioned were conducted with standard or acid lead arsenate. Neutral (diplumbic or triplumbic) lead arsenate, in experiments at Washington, D. C., applied at standard dosage, caused no injury to bean foliage.

left these plants at once. Larvæ hatching from eggs deposited before the application of the poison were also killed where they fed on sprayed leaves. The older larvæ, however, appeared to die of starvation rather than from eating the poisoned foliage.[1]

ARSENITE OF ZINC.

Experiments were made with powdered arsenite of zinc at the rate of 1 pound to 20, 30, 40, and 60 gallons of water, respectively. The burning effect on the foliage was in all cases less than where arsenate of lead or Paris green was applied, and usually a larger proportion of the insects was killed. The burning was most apparent about the margins of the holes made in the leaves by the insects in feeding. Many larvæ died after eating the poisoned foliage, but, as with the other arsenicals, the effect on the beetles was uncertain. All factors considered, the most promising results were obtained with zinc arsenite at a strength of 1 to 40. This caused comparatively slight burning and killed an appreciable number of the insects. It should not be overlooked, however, that the killing of the beetles is uncertain and that the burning effect on the plants will vary greatly with their age and tenderness. It is probable that Mexican beans, with relatively tougher foliage, would show less injury from burning than the more tender-leaved string beans treated in these experiments. Zinc arsenite in experiments conducted in New Mexico by Merrill at the rate of 2 pounds to 50 gallons of water produced practically the same results as powdered lead arsenate.

PARIS GREEN.

Experiments were made with Paris green at the rate of 1 pound to 60 and to 80 gallons of water. As a result of these tests the beans were destroyed by burning due to the presence of free arsenic. Most of the larvæ were killed, but many of the beetles escaped. In the face of these results, Paris green at these strengths can not be recommended as a means of controlling the bean ladybird. Everyone who has tried Paris green has experienced the same failure. Sodium arsenite is at least equally dangerous.

SUMMARY OF SPRAYING EXPERIMENTS.

The experience of entomologists in spraying with arsenicals in Colorado and New Mexico tends to show that arsenate of lead acts largely as a repellent rather than as an insecticide, which is true also of its effectiveness in the case of such other pests as the striped cucumber beetle.

Bordeaux mixture, which has come to be considered a standard repellent against flea-beetles, should be tested against the bean ladybird in the future.

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[1] Powdered lead arsenate at the rate of 5 pounds to 50 gallons of water was no more effective but did no damage to the plants in experiments made. It should not be used at this strength.

Additional experiments are necessary with arsenate of lead and arsenite of lime, alone and in combination with Bordeaux mixture.

NICOTINE SULPHATE INEFFECTIVE.

In another series of experiments larvæ about one-fourth grown were sprayed with nicotine sulphate at the rate of 1 ounce to 2, 4, and 6 gallons of water, respectively. The larvæ apparently were protected by their spines and the applications were in all cases absolutely ineffective. The only noticeable effect was that the larvæ appeared somewhat stupefied for a brief interval.

COOPERATION.

In the control of this pest, as with so many others which are difficult to destroy, combined effort on the part of the bean growers of the community is essential to success. Whatever can be done in cooperation to lessen the numbers of this insect in one season is felt the next season and if it were rigidly continued would mean the eventual saving of the crop.

SUMMARY OF CONTROL MEASURES.

In the light of our present knowledge the best methods of controlling the bean ladybird may be summarized as follows:

(1) For small gardens and similar areas hand pick the overwintered beetles as soon as possible after they emerge from hibernation.

(2) Brush the larvæ, or young, from the plants during hot, dry weather.

(3) Spray with arsenite of zinc, at the rate of 1 pound to 40 or 1½ pounds to 50 gallons of water, or with arsenate of lead 1 or 2 pounds (powder) to 50 gallons of water.

(4) Clean up the fields by removing dead grasses, weeds, and other possible hibernating quarters during the fall or winter months, and destroy them by burning, or by simply burning over the fields when this practice can be safely followed.

(5) Early and late planting should be practiced. No specific time can be indicated for this that would apply to the entire region which the insect inhabits, and it is more satisfactory for the growers to work out this problem for themselves.

(6) In the case of large areas of beans, close inspection is strongly recommended. Infestation usually begins in small, localized areas, and if these infested spots are located and prompt measures, as indicated in the preceding paragraphs, are taken to destroy the insects a general infestation can be prevented.

GENERAL SUMMARY.

The bean ladybird is a serious pest on beans of all kinds, including the soy bean, in Colorado, New Mexico, Arizona, and western Texas. It frequently destroys entire crops and the conservative estimate of the annual losses incurred is placed at 10 per cent of the crop. This insect feeds normally on the leaves, and attacks also the young pods and occasionally eats into the blossoms. The beetles feed

chiefly on the upper surface, cutting irregular holes in and through the leaves, while the larvæ feed on the lower surface and skeletonize the leaves, seldom cutting through them.

The adult is a robust beetle, about one-fourth inch in length, of oval outline, pale brown, with each wing-cover marked with eight small black spots. The larva is light yellow and armed with branched spines.

The yellow eggs are deposited from about the middle of June until August on the lower surface of the leaves, in clusters of 40 or more, and sometimes to the number of 1,500 by a single female. The larvæ feed at first in colonies, but with larger growth scatter and become more or less solitary. The life cycle may be passed in summer in from 22 to 30 days; the eggs hatch in from 4 to 9 days; the larval period is between 15 and 21 days; and the pupal period varies from 3 to 6 days. In colder weather, however, these periods are longer. Two generations or "broods" are produced annually.

FIG. 5.—Traction sprayer with nozzle arrangement for side spraying, of type useful for spraying beans for the bean ladybird.

Cold weather in late autumn has the effect of destroying the insects, and their eggs are also destroyed by three species of predacious ladybirds.

In the control of the bean ladybird preventive measures are the most efficient, consisting of hand picking and brushing from the plants, clean culture, and early and late planting. Arsenicals possess some killing properties, but in the main act as repellents. Spraying with arsenate of lead, 1 or 2 pounds (powder), and with arsenite of zinc, 1 to 1½ pounds (dry), to 50 gallons of water, are the most promising. Bordeaux mixture, 4–4–50 formula, should be used alone and in combination with these arsenicals. Additional tests must be made with these substances to ascertain the most effective and economical combination that may be applied to the bean plants without scorching or burning the leaves.

For the treatment of large areas infested by the bean ladybird, a traction sprayer with nozzles arranged for side spraying of the type shown in figure 5 is useful. Owing to the danger of scorching bean foliage, it is desirable that an up-to-date sprayer should always be used.

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THE BEAN LADYBIRD IN COLORADO IN 1919.

By A. E. MALLORY, *Scientific Assistant.*

LIFE-HISTORY RECORDS.

Hibernating adults of the bean ladybird which had passed the winter successfully began to appear in Colorado in 1919 about the middle of June, the first individuals having been found June 16 feeding on beans. A week to 10 days later they began to deposit eggs on the underside of the leaves in clusters of about 40 or more. About 2 weeks later, July 9 and 10, the eggs hatched, and the tiny yellow larvæ commenced to feed in a colony near the egg cluster. As they grew older they became separated and did not necessarily confine their feeding to the underside of the leaf. As the season advanced, they fed on every part of the plant, blossoms and pods included. The larvæ were present in all stages from the first appearance until at least September 10. On July 22, which was 10 or 12 days after the eggs had hatched, pupæ were found. During the early part of the season, when foliage is plentiful, pupation takes place on the underside of the leaf. In case the foliage has been extensively destroyed pupation may take place on either side of the leaf or on both sides, 25 to 30 pupæ on a single leaf being not uncommon. As many as 100 on a single leaf were reported in a case where infestation was heavy. This congregating at the time of pupation seems to be characteristic of the species. Pupæ were observed on other plants near beans when the foliage of the beans was almost destroyed.

On July 28 adults of the first brood were observed, and by July 30 they were numerous, gradually increasing in number until about September 1 when they seemed to reach their maximum numbers. The first-brood adults are much lighter in color than the hibernating individuals, being a bright yellow at the time of emergence. They gradually become darker, and at hibernating time some are dark reddish brown, almost if not entirely as dark as the hibernating individuals. Eggs deposited by this new brood were observed August 28 and September 2. It is possible that eggs were deposited by this brood earlier than these dates.

There is no definite place in the life history of this species to separate the different broods. Apparently there are two broods or at least a partial small second brood for this locality. The fact that larvæ were observed in all stages of development during the entire season would suggest two broods. Further, the fact that first-brood adults began issuing rather late, and that so few egg clusters were found in late August and September, would suggest only a partial second brood.

SUMMARY FOR 1919.

Hibernating adults appeared	June 16.
Beetles present in large numbers by	June 25.
Beetles began depositing eggs	June 25.
Eggs began hatching	July 10.
Larvæ began to transform to pupæ	July 22.
Adults of first generation issued	July 28.
Egg clusters, second brood, found	August 28. to September 2.
Maximum numbers first-brood adults observed	September 1.
Adults began to become sluggish	September 10.
Maximum damage accomplished	August 1 to September 1.

Second-brood eggs were probably deposited, but not observed, before August 28.

INJURY.

The bean ladybird so far as observed confines its feeding to beans, and when taken on other plants is never found feeding. The variety of beans seems to make no particular difference as to susceptibility to attack. The adults do not attack the very young plants to any considerable extent. This fact is probably due to the small number of hibernating individuals. Furthermore, the overwintering adults do not concentrate their attack, but move from plant to plant. Thus the damage is less noticeable. Although the adults usually eat entirely through the leaf, they often merely scrape the surface, leaving a network of veins plainly visible. Later in the season as the foliage begins to die they attack the pods, sometimes completely riddling them, but usually eating out small spherical holes here and there along the pod. In the case of canning beans this injury may cause considerable loss, while on seed beans it is not so serious.

The percentage of injury by a number of adults is small as compared to that caused by an equal number of larvæ. The larvæ begin their attack on the leaves, invariably feeding at first on the underside. Instead of eating through they scrape the surface, leaving the skeleton of the leaf in plain view, although with continued feeding in a limited space they may riddle the foliage.

Maximum damage occurred in this locality during the month of August. This is the period when the new adults are feeding along

with the larvæ, and the two broods of larvæ overlap. Damage was generally worst near fences, along ditch banks, and on beans receiving an extra amount of water by accident or seepage.

There is a large area in northeastern Colorado devoted to farming and stock raising. This area is known as the Greeley District. Beans of all varieties are grown quite extensively. Several thousand acres are planted to beans every year. A conservative estimate of the damage done to the whole bean crop in that district during the season of 1919 by the bean ladybird is about 5 per cent. This estimate at first may seem rather small, but the majority of fields were infested lightly or not at all. In the second place a few fields were more heavily infested than the adjacent or neighboring fields. In those fields coming under our observation the damage by *Epilachna corrupta* varied from an estimated 25 per cent to 65 per cent. One field in particular, of about 15 acres, was damaged at least 65 per cent if not 75 or 80 per cent. No remedial measures were applied in this case.

CONTROL.

In some of the small truck patches the attack of the bean ladybird was controlled by hand picking. In view of the distribution of the damage, as stated, clean farming or destruction of winter quarters is suggested as an important measure of control.

As to remedial measures, all possibilities were not worked out. On July 10 when the first larvæ were observed, the following sprays were tested on large plots in a 9-acre field. Right-angle mist-producing nozzles were used. Approximately 80 per cent of the leaves were covered on one side or the other, the remainder varying from a small amount to none at all. The foliage was heavy.

Experiment No. 1.—Lead arsenate, powder, was used at the rate of 2 pounds to 50 gallons of water, with 2 pounds of hydrated lime added. Very little if any damage was noted from the spray. A few dead larvæ were found.

Experiment No. 2.—Lead arsenate, paste, was used at the rate of $2\frac{1}{2}$ pounds to 50 gallons of water. No damage to the plants was noted.

Experiment No. 3.—Zinc arsenite, paste, was applied at the rate of 2 pounds to 50 gallons of water. This strength caused no damage to the plants.

Experiment No. 4.—Bordeaux mixture, alone, formula 3–6–50, was applied to a plot. No damage was done to the plants. This application seemed to be as effective as any of the foregoing during the earlier part of the season, but this plot showed a greater maximum damage after August 1 than did any of the others. The remainder of the field and a second field of 21 acres were sprayed with

the same material and formula as number 1, viz, 2 pounds of lead arsenate, 2 pounds of hydrated lime, and 50 gallons of water.

Observations following these applications revealed a few dead larvæ. To locate dead larvæ was a difficult matter. Our opinion is that many were killed at the first feeding. If not killed then or very soon after, they fed to maturity. Up to August 1 all remedies tried seemed to be equally effective, the amount of damage to the plant being about the same for each plot. Undoubtedly these insecticides held the beetles and larvæ in check. The 9-acre field had an unusually large number of hibernating beetles. After August 1 the damage seemed to increase quite rapidly, and was worse on the Bordeaux plot than on any of the others. A small unsprayed plot was entirely destroyed, most of the injury here being done before August 1.

A second spraying two weeks later, about July 25, might have almost if not entirely controlled the attack.

In A. B. Owen's field of 9 acres, where spraying experiments were conducted July 10 and 11, the estimated damage was 12.5 per cent. It is believed that approximately 65 per cent of the larvæ hatching before July 25 must have been killed by the lead arsenate or zinc arsenite. The number of adult beetles found in this field in early July undoubtedly was large enough to have damaged the crop to the same extent as in the special field mentioned above. This experiment, while not of the type anticipated, demonstrates that the attack of this species can be controlled by the use of either lead arsenate or zinc arsenite.

A second spraying between July 25 and August 1 is recommended as very promising in controlling the insect, since it is at about this time that the second brood begins to appear. The two broods overlap, and the damage they do begins to increase very rapidly from this time on.

The combination spray consisting of Bordeaux mixture and an arsenical is also a promising experiment. Undoubtedly the Bordeaux mixture, in case it proves a repellent against this insect, will serve as an important fungicide. It will add very little to the expense of spraying, and will possibly increase the yield several bushels per acre by controlling minor fungous diseases.

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